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SOLIFLUCTION LOBE DYNAMICS IN THE SOUTHERN CANADIAN ROCKY MOUNTAINS

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SOLIFLUCTION LOBE DYNAMICS IN THE SOUTHERN CANADIAN ROCKY MOUNTAINS

Introduction

Solifluction landforms are an integral morphological component of high alpine areas of the North American cordillera. Although they clearly represent an important mass wasting process of this zone, detailed investigations of their nature and dynamics are limited to two studies. This includes Benedict's (1970) examination of downslope movement in the Colorado Front Range and Price's (1970) documentation of solifluction lobe ecology in the Yukon Ruby Range. Within the southern Canadian Rockies there has been almost no appreciation of the geomorphic significance of solifluction processes (c.f. Luckman, 1981). S. Harris (1972, 1973) and Luckman (1973) have confirmed the activity of slow mass wasting processes in this region but did not specifically distinguish the role played by solifluction.

The purpose of this paper is to present the results of several years of study into solifluction lobe activity in the Canadian Rockies. Data will be presented which is used to describe the rate of contemporary and historical solifluction activity.

Solifluction Processes

Solifluction mass wasting is an important component of the fine sediment cascade on mountain slopes (Caine, 1974). Of the suite of geomorphic processes influential in promoting solifluction activity, frost creep and gelifluction are the most significant. To some extent the frost creep component is the easier to distinguish since the downslope movement generated is a function of the local slope and the magnitude of seasonal frost heaving. However, retrograde controls reduce the absolute movement (Washburn , 1967) and some ambiguity results when calculations designed to deduce potential frost creep are applied to field

situations (C. Harris, 1981).

Gelifluction occurs as the result of saturated soil flow during the spring thaw period. It is most effective when excessive moisture is released into the upper soil horizons, such as occurs following seasonal ground heave. The explicit role played by each process thus becomes difficult to assess as they commonly operate together (Benedict, 1970). However, an estimate of the part gelifluction plays in total mass wasting can be qualitatively demonstrated if the potential frost creep is known.

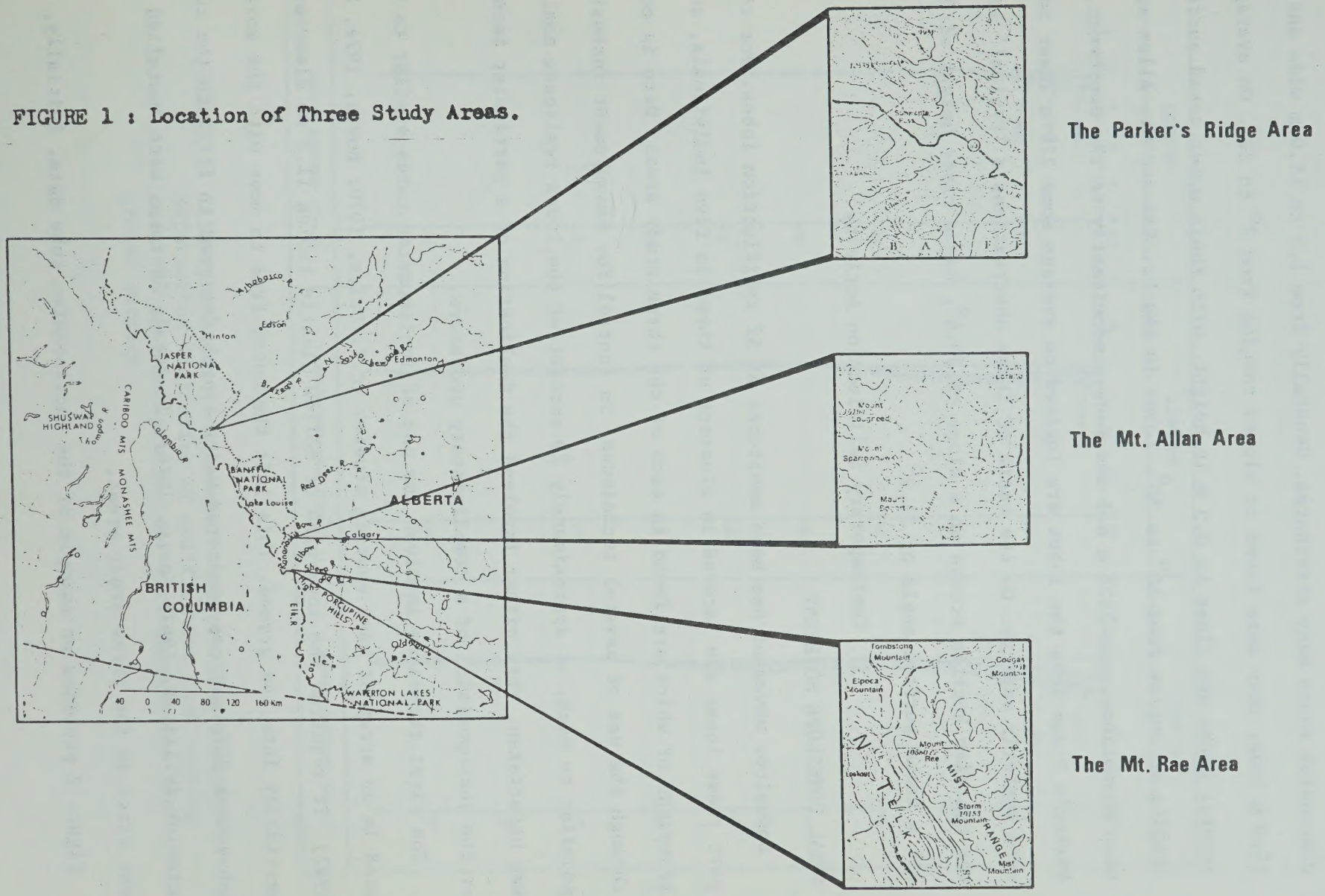
Within the Canadian Rockies a wide range of morphological features are indicative of solifluction activity (Gardner, Smith, Desloges, 1983). The turf-banked lobes selected for study are indicative of concentrated solifluction motion and are represented in most high alpine areas. Easily recognized by their tongue-like appearance, they are usually well-vegetated and lacking in conspicuous sorting (Benedict, 1970).

Study Area

Research into solifluction processes is underway at three locations in the southern Canadian Rockies (Figure 1). The principal investigation site is the Mt. Rae area (Lat. 50° 36', Long. 114° 38') located in the southeast corner of Kananaskis Provincial Park. Complimentary sites are located in the vicinity of Mt. Allan (Lat. 50° 57', Long. 115° 11') in Kananaskis Country and on Parker's Ridge (Lat. 52° 11', Long. 117° 06') in northern Banff National Park. Research activities were initiated in 1977 in the Mt. Rae area, in 1980 in the Mt. Allan area and in 1981 in the Parker's Ridge area.

During reconnaissance of the three study areas solifluction lobes were discovered in a wide variety of settings, from seasonally xeric ridge-top summits to lush moist alpine meadows. Despite this locational variability, the lobes under

FIGURE 1 : Location of Three Study Areas.



The Parker's Ridge Area

The Mt. Allan Area

The Mt. Rae Area

discussion share many attributes. Generally from 1.5 to 15.0 m wide and up to 15.0 m long, they were found on slopes ranging from 7^{o} to 32^{o}. On average their frontal banks are close to 0.5 m in height, with their upper tread surfaces sloping at angles from 10^{o} to 30^{o}. Lobes in the Mt. Rae and Mt. Allan areas have mean elevations near 2425 m asl and face predominantly to the southwest. In the Parker's Ridge area the lobes are located on average some 270 m lower and have more easterly aspects. On the basis of these observations a 'typical' lobe in the Canadian Rockies occurs on a slope of 20.4^{o}, has a riser height of 0.45 m and a tread surface angle of 21.9^{o}.

Contemporary Solifluction Activity

TOTAL DOWNSLOPE MOVEMENT

Downslope movement has been monitored at 52 solifluction lobes. For the most part these lobes are located in clusters of three to five individuals, several groupings of which are found in each of the three study areas. Data is collected through the use of several techniques. To control for measurement insensitivities peculiar to each, at approximately 20 percent of the lobes replicate monitoring was undertaken. This either involved the duplication of a particular technique or the juxtoposition of a complimentary procedure.

The first technique involved the use of inclinometer tubes similar to those used in an array of mass wasting studies (c.f. Price, 1970; Bovis, 1974, MacKay, 1981). It required the insertion of hollow plastic tubing (1.9 cm diameter) vertically into the ground. This left the tubes free to move with the soil, with subsequent deformations monitored using a probedesigned to fit into the tube interior (Williams, 1962; Bovis, 1974). In total, 59 tubes were installed at 48 lobe sites in the three study areas.

Figure 2 provides an example of the inclinometer tube data. Initially,

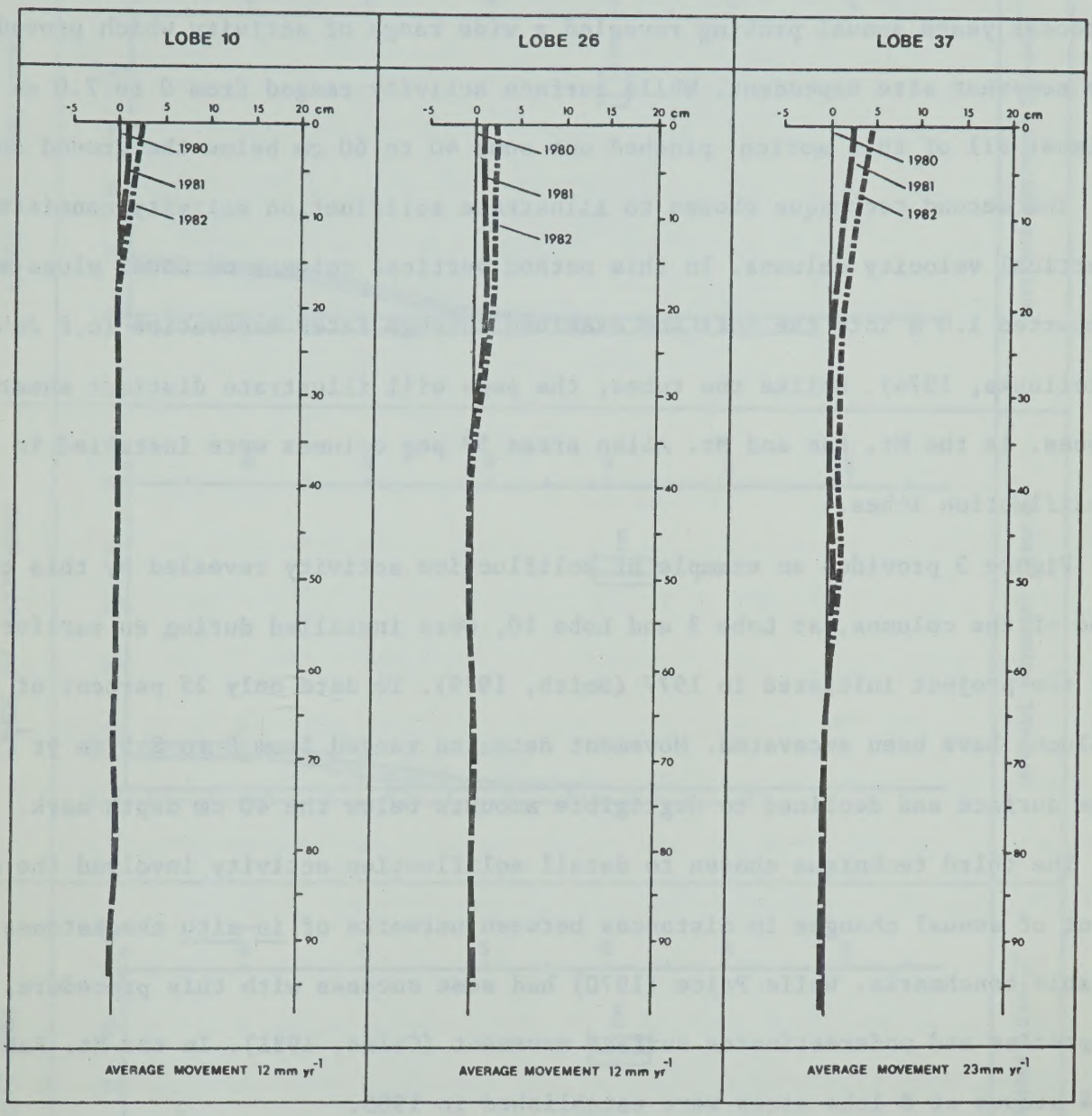


FIGURE 2: Illustration of inclinometer tube profiles showing deformation indicative of solifluction mass wasting. Note how movement pinches out with depth below the ground surface.

sensitivity of the probe led to some exaggeration of the profiles. However, excavation of in-situ tubes provided a workable reduction factor. Over the two process years annual probing revealed a wide range of activity which proved to be somewhat site dependent. While surface activity ranged from 0 to 7.0 cm yr^{-1}, almost all of this motion pinched out some 40 to 60 cm below the ground surface.

The second technique chosen to illustrate solifluction activity consisted of vertical velocity columns. In this method vertical columns of dowel plugs were inserted 1.0 m into the soil and examined through later excavation (c.f Jahn and Cielinska, 1974). Unlike the tubes, the pegs will illustrate distinct shearing zones. In the Mt. Rae and Mt. Allan areas 58 peg columns were installed in 31 solifluction lobes.

Figure 3 provides an example of solifluction activity revealed by this technique. Two of the columns, at Lobe 3 and Lobe 10, were installed during an earlier phase of the project initiated in 1977 (Smith, 1979). To date only 25 percent of the columns have been excavated. Movement detected ranged from 0 to 2.5 cm yr^{-1} at the surface and declined to negligible amounts below the 40 cm depth mark.

The third technique chosen to detail solifluction activity involved the measurement of annual changes in distances between networks of in-situ checkstones and stable benchmarks. While Price (1970) had some success with this procedure, it is imprecise and underestimates surface movement (Caine, 1981). In the Mt. Rae area 124 stones at 8 lobe sites were established in 1980.

Figure 4 illustrates surface activity detected by this technique at one site in the Mt. Rae area. Average yearly movement recorded ranged from 0.3 to 1.1 cm yr^{-1} of surface activity. Comparison of this data with that described by the two other techniques suggests this methodology understates the actual movement by 25 to 50 percent.

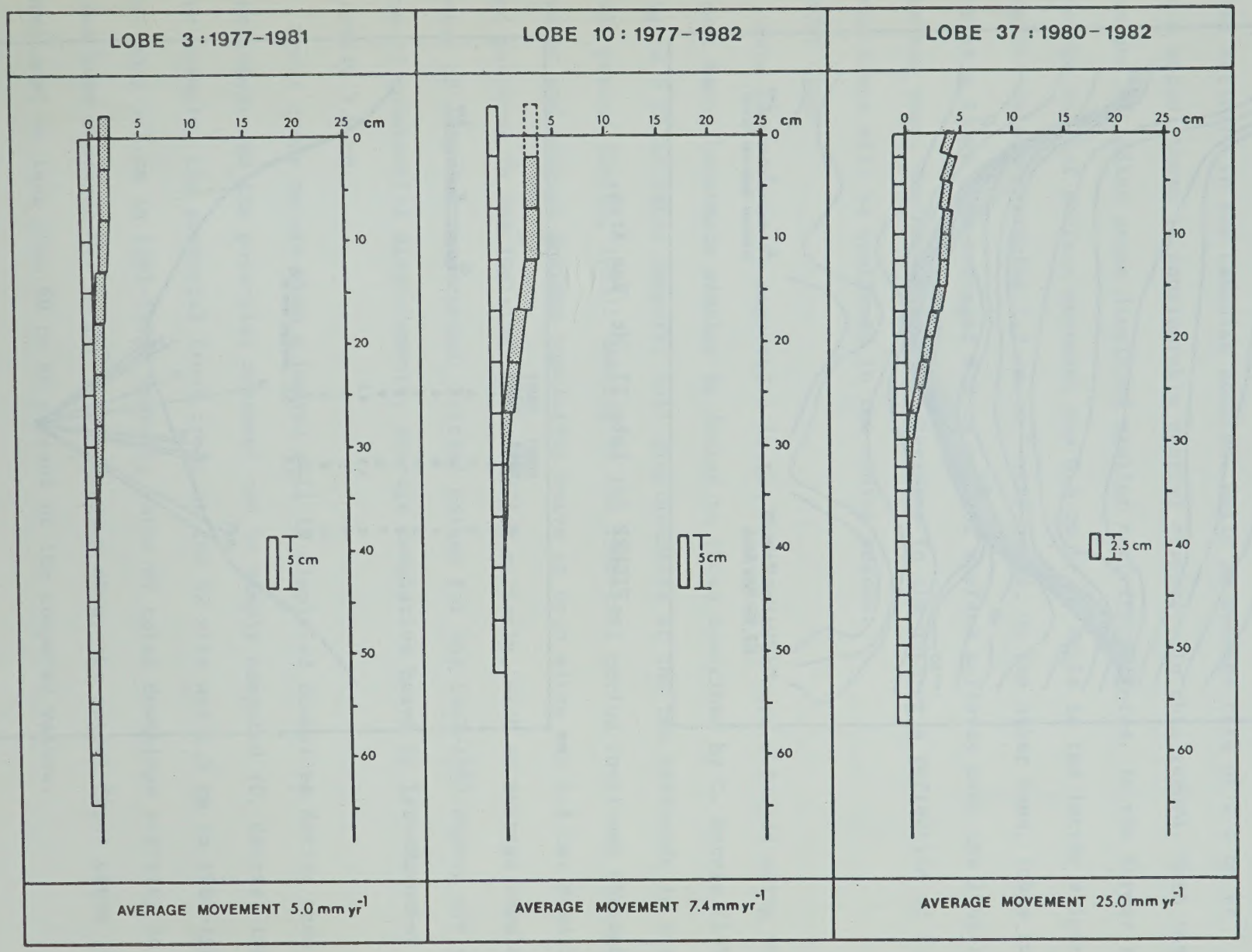

LOBE 3 : 1977–1981
LOBE 10 : 1977–1982
LOBE 37 : 1980–1982
0 5 10 15 20 25 cm
0 10 20 30 40 50 60
5 cm
5cm
2.5 cm
AVERAGE MOVEMENT 5.0 mm yr-1
AVERAGE MOVEMENT 7.4 mm yr-1
AVERAGE MOVEMENT 25.0 mm yr-1

FIGURE 3: Illustration of vertical velocity column profiles showing deformation indicative of solifluction mass wasting.

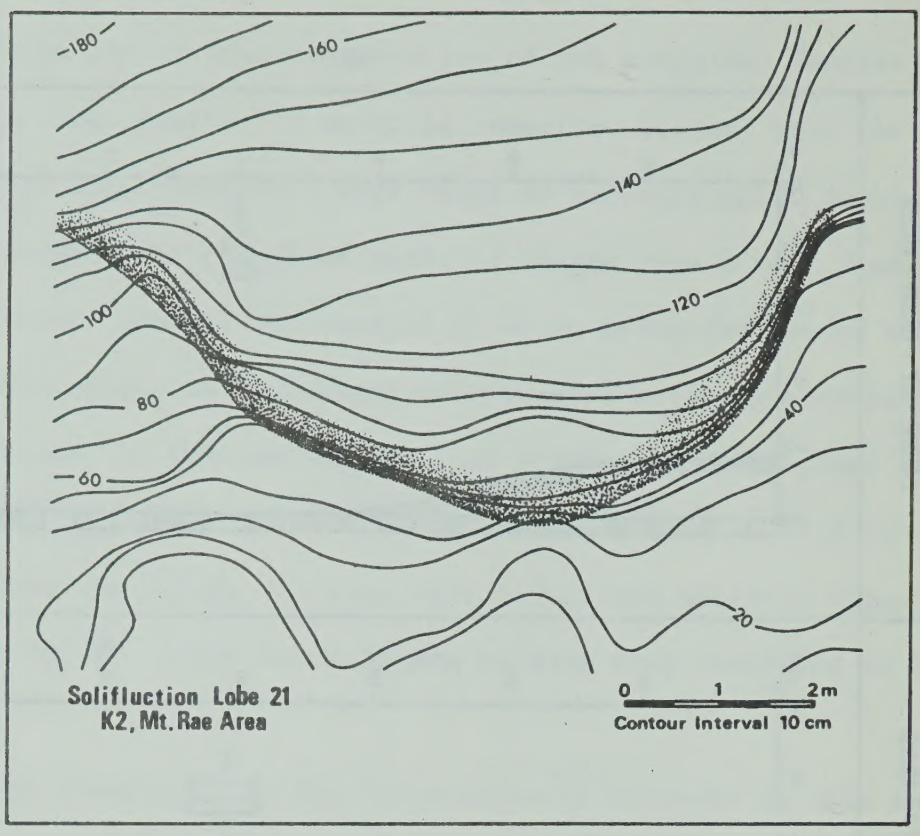


FIGURE 4a: Lobe 21, Mt. Rae Area.

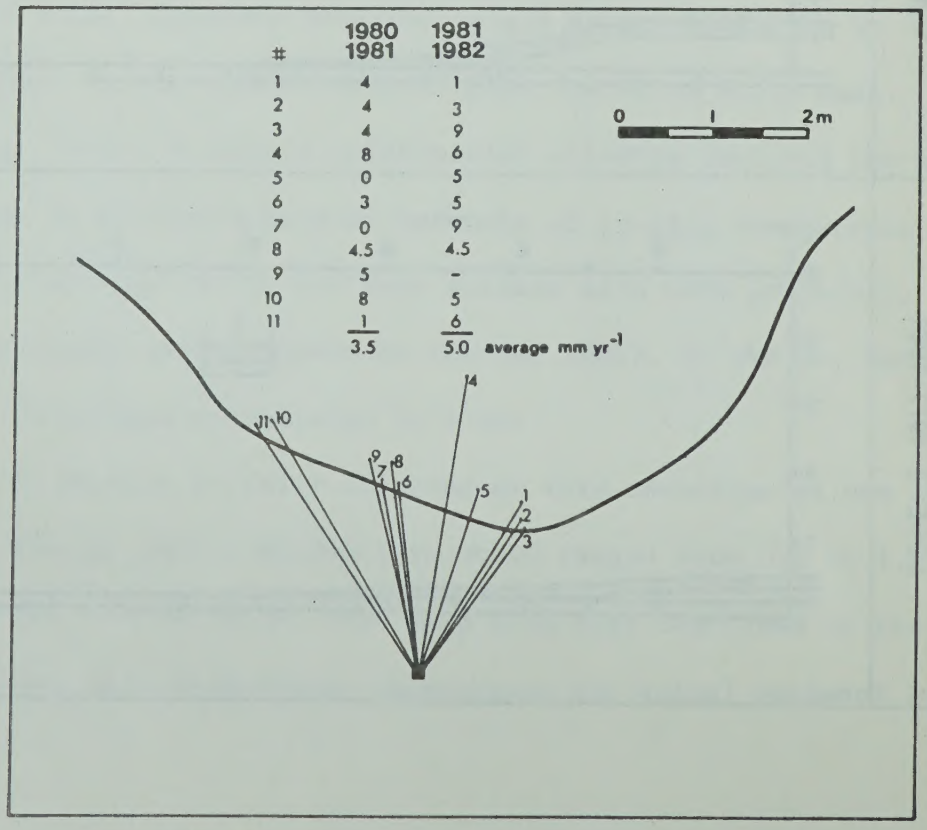


FIGURE 4b: Stone movement network, Lobe 21.

Examination of this data base permits preliminary discussion of solifluction lobe activity in the Canadian Rockies. While an average rate of 2.1 cm yr^{-1} has been noted, there is considerable spatial disparity in this record. Both the Mt. Rae and Mt. Allan areas displayed similar activity patterns. In the former the average rate of surface movement was 0.9 cm yr^{-1}, while in the latter slightly greater values averaging 1.3 cm yr^{-1} were noted. On the other hand, lobes in the Parker's Ridge area averaged 4.2 cm yr^{-1} of surface activity over the 1981-1982 process year. Whether this is an aberation in the data or a reflection of local conditions will be confirmed in the coming season.

FROST CREEP

Data on frost heave magnitudes in the Mt. Rae area were obtained using two frost heave bedsteads similar in design to those described by C. Harris (1971). Figure 5 illustrates temporal soil displacements at the two bedsteads in the 1980-1981 period (Smith, 1983). Heaving in the 1980-1981 period continued through the winter and average maximum cumulative heave at both sites was 4.5 cm. Magnitudes and patterns in the 1981-1982 period differ markedly, with an average cumulative heave of only 2.9 cm recorded. Initial values for the 1982-1983 season are suggestive of substantial displacements. Average cumulative heave by late-November was already 3.9 cm.

Frost creep occurs when a heaved soil is displaced downslope during thaw settlement and the potential movement can be simply computed (C. Harris, 1981:76). For example, the potential frost creep at the K2 site was 1.5 cm in 1980-1981, but only 1.1 cm in 1981-1982. However, rates of total downslope activity in this area have averaged 0.9 cm yr^{-1}. At a maximum then, the actual frost creep in this area must be less than 60 to 80 percent of the computed values.

SUMMARY

These data illustrate that solifluction processes are an active component of

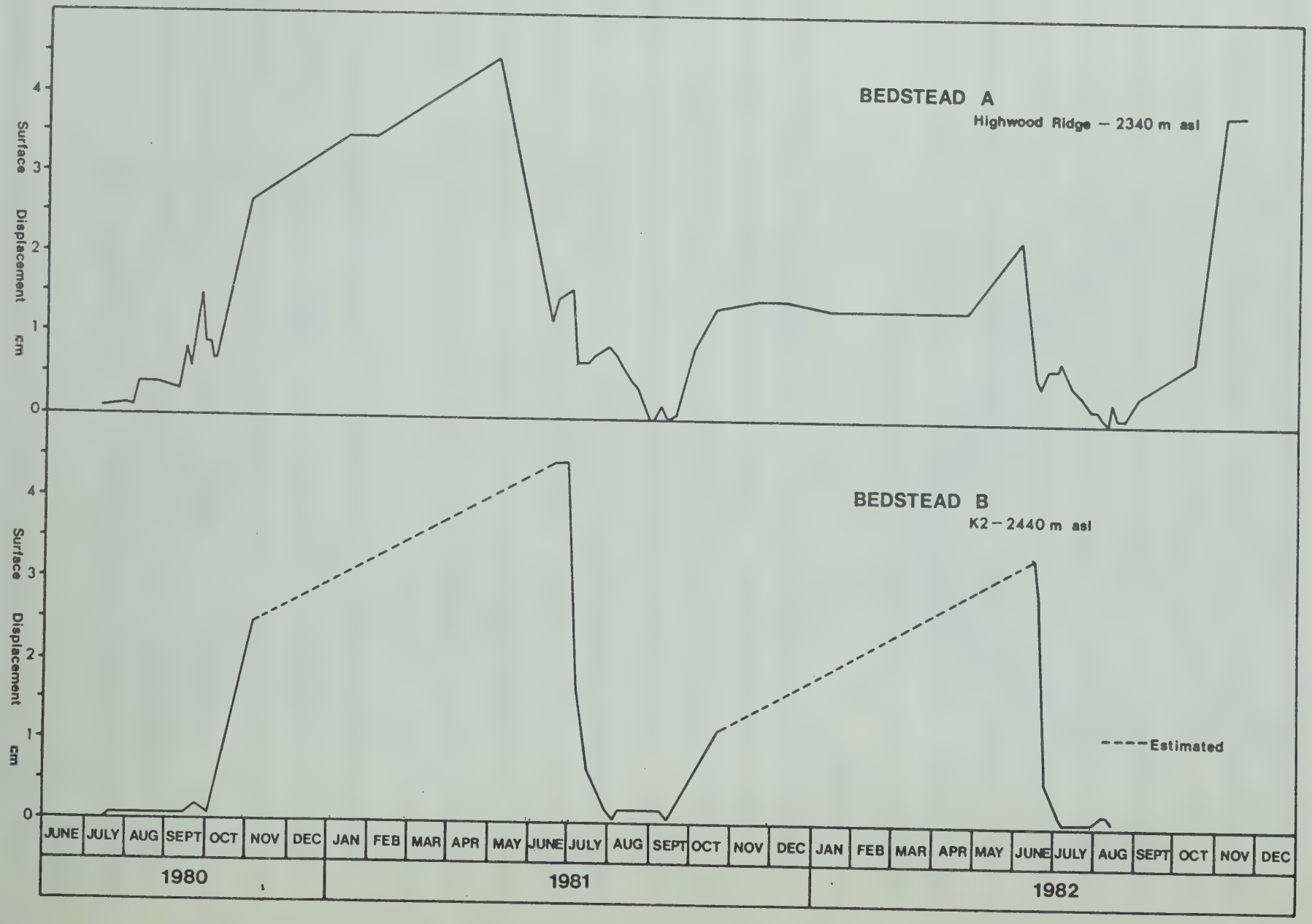


FIGURE 5: Frost Heave Measurements in the Mt. Rae Area (1980-1982)

mass wasting in the Canadian Rockies. Average rates of surface activity show considerable spatial diversity from the Kananaskis front ranges to the Columbia Icefields area. Calculation of potential frost creep in the Mt. Rae area leaves open the question of the relative significance of frost creep and gelifluction processes to local solifluction mass wasting.

Historical Solifluction Activity

Several methods have been used to estimate long-term rates of solifluction lobe activity. In particular, radiocarbon dating of organic soil horizons overriden by advancing solifluction lobes has proven to be a powerful tool (c.f. Alexander and Price, 1980; Dyke, 1981; Gamper, 1981). However, despite widespread application errors inherent in the radiocarbon dating of soils necessitate circumspect conclusions (c.f. Scharpenseel and Schiffman, 1977). Especially in alpine environments where the naturally occurring organic pool can decay very slowly, radiocarbon dating illustrates soil ages of considerable spectrum (c.f. Matthews, 1980).

STUDY SITE

In July of 1980 Solifluction Lobe 1 in the Mt. Rae area was trenched to a point some 12.0 m behind the current riser front. A buried soil horizon, including an upper organic layer, was revealed in the cross-section. Samples of the orgainc layer were subsequently submitted for radiocarbon dating to the Brock University (BGS) laboratory.

Lobe 1 sits within an alpine tundra valley at 2370 m asl, some 30 m above the local tree-line. Facing to the northwest it is over 10 m across at its widest point. Its upper tread surface angles at 7.5^{o} near the snout, while the local slope being overriden is close to 14.0^{o}. At its snout the lobe riser is 0.31 m in height.

Vegetation communities below the lobe are dominated by dense mats of arctic willow (Salix arctica), Juncus drummondi and Arnica mollis. The lobe riser displays a more diverse mixture of plants with large percentages of mosses and lichens appearing. On the lobe surface snow willow (Salix nivalis) and yellow heather (Phyllodoce aleutica) provide a scanty vegetation cover.

The lobe is composed of s silty-sand diamicton with a few angular cobbles and blocks. This debris has a liquid limit near 56 percent but no apparent plasticity. In front of the lobe an Alpine Dystric Brunisol developed within glacial till is being overriden.

Evidence for contemporary solifluction activity is equivocal at this site due to the short measurement period. Data collected to date (1980-1982) suggests surface motion is slightly less than 0.5 cm yr^{-1}. There is little evidence to indicate movement deeper than 20 cm from the lobe surface at the present time.

RESULTS

Figure 6 illustrates the array of radiocarbon dating complied to date at Lobe 1. Two thousand years of solifluction activity are illustrated, during which the lobe advanced between 0.34 to 1.54 cm yr^{-1}.

Attempts to place an absolute time frame on this historical activity are problematic since it is recognized the organic horizon had a ^{14}C age prior to burial. Corrected dates can only be retrieved if a standard age for the organic mat at the time of burial is established. Unfortunately, there have been few attempts to determine the radiocarbon age of modern organic layers in alpine areas of the North American cordillera. Values of 390 ± 120 established by Benedict (1970) and 340 ± 120 used by Alexander and Price (1980) would be difficult to apply in this situation. Speculation of a mean residence age is better served by the recent work of Scotter and Zoltai (1982) in the Sunshine Meadows along the

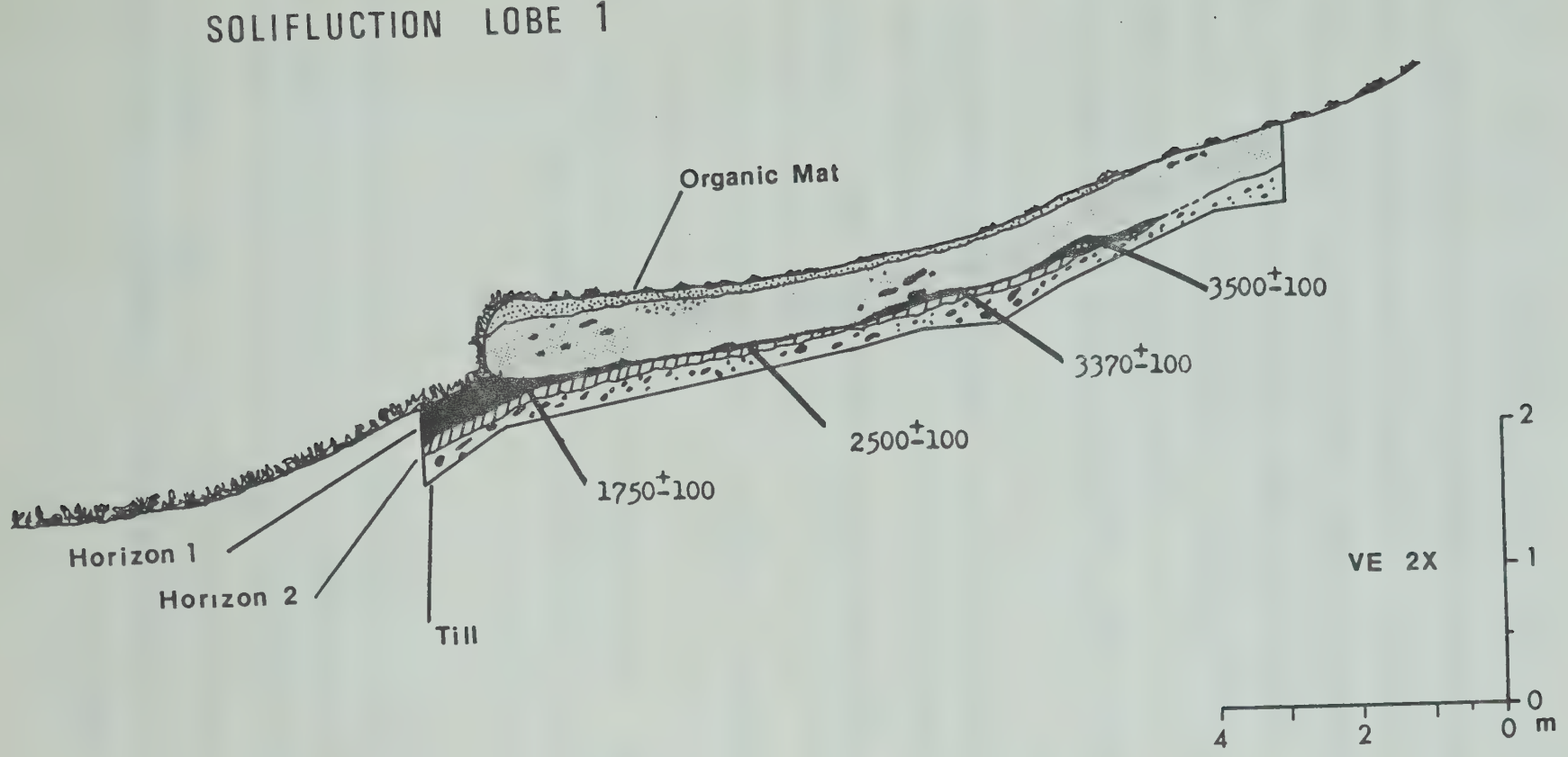


FIGURE 6: Cross-Section and Location C_{14} Samples, Lobe 1, Tombstone Valley

Continental Divide. In their study, an undisturbed Ah horizon 5-8 cm below the surface of an earth hummock yielded an age of 1680 ± 100 (BGS-696). Application of this soil age in the present context appears quite reasonable. Assuming Lobe 1 continued to advance at the same rate it had in the last dated time frame (0.47 cm yr^{-1}), it would have reached its present snout position approximately 150 years later. If this is true, then the radiocarbon age of the soil was around 1600 years at the time of burial. This similarity in soil age between the two areas is striking and enables discussion of this dating series in the contex of real time.

Estimates of the corrected temporal positioning of the lobe front imply there has been little change in the rate of lobe front movement (3.4 to 4.7 mm yr^{-1}) in the last 1700 years. While the spacing of these ^{14}C samples does not preclude the possibilty of short-term changes, it is apparent long-term changes in the rate of solifluction activity at this site have not reflected climatic epsiodes thought to have occurred in the late-Neoglacial period (c.f. Ferguson, 1978; Kearny, 1981). Enhanced solifluction prior to 1690 yrs. B.P. (15.4 mm yr^{-1}) is enigmatic, although it may be related to an earlier phase of climatic change (Kearny, 1981).

SUMMARY

The historical nature of solifluction activity in the Mt. Rae area illustrates an insensitivity to major climatic episodes which occurred during the late-Neoglacial period. In particular, there is little evidence to indicate a response to deteriorating conditions which accompanied the Little Ice Age. In summary, it appears that climate may not be a significant factor influencing solifluction movement in this area (c.f. Dyke, 1981).

Conclusions

The preliminary results of this research project have illustrated the contemporary activity of soliluction processes in the Canadian Rockies. The data has indicated significant spatial variation in the rates of activity, particularly between the northern and southern sites. However, there is little indication to date of significant temporal variations in the rate of solifluction mass wasting over the record period.

Radiocarbon dating of a buried soil from beneath one lobe in the Mt. Rae area indicates continuous solifluction motion throughout the late-Neoglacial period. Long-term rates of activity illustrated are similar to those recorded over the past few years. This may indicate an insensitivity on the part of local solifluction processes to climatic episodes such as the Little Ice Age.

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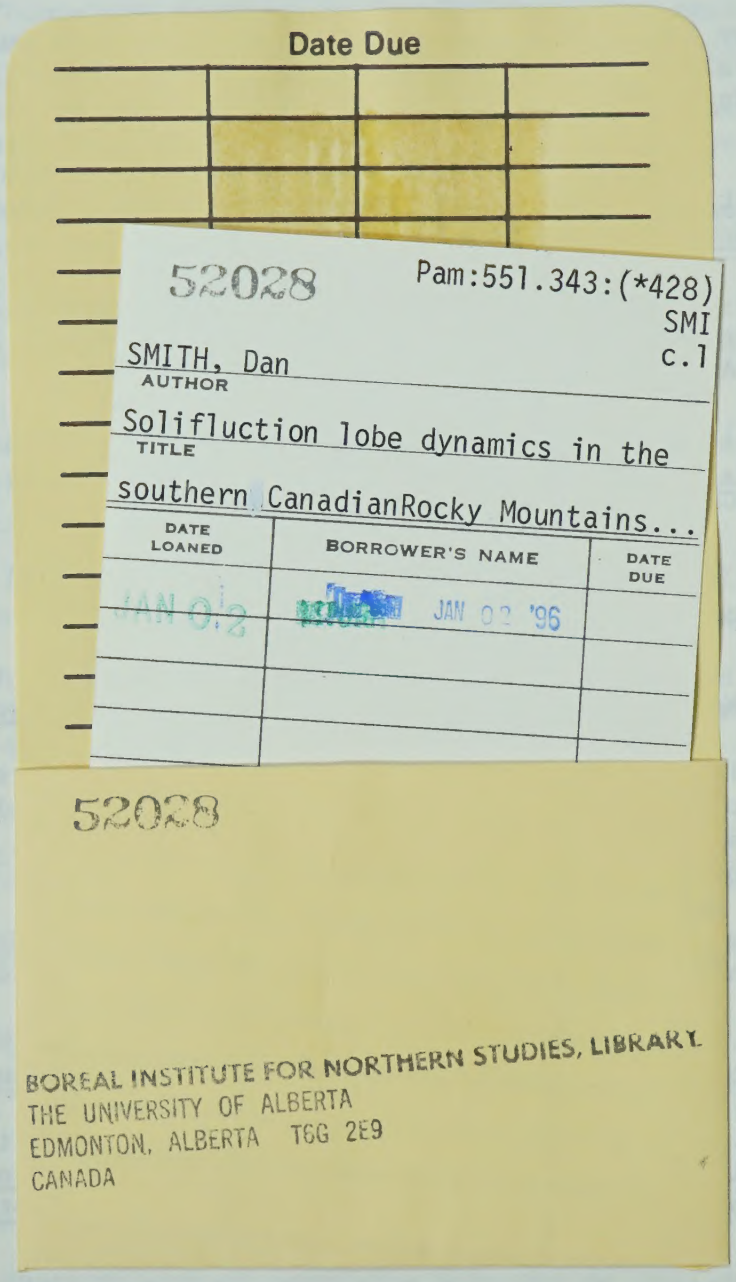
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